PLACEMENT IMPACT OF DISTRIBUTED GENERATION IN DISTRIBUTION NETWORKS

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ABSTRACT

The Distributed Generation (DG) penetration in distribution network has been slowly increasing for the last few years due to advancement of technologies and institutional changes in the electric power industry. DG has gained popularity as it seen to be the reliable option for solving major problem in electric power industry such as reduce high loss, decrease line losses, improving voltage profile at feeders and environmental effect. As the DG was popular, it is in the best interest of all players to allocate the DG to minimize the system losses thus improving voltage profile. This paper aims to find the optimal location for placing DG in distribution network to minimize the total power losses in distribution network, to propose the network improvement based on the presence of DG. The methodology starts with running the distribution load flow program to find the state of the bus systems. The base case load flow was simulated in DigSILENT PowerFactory to find the potential location for placing the DG. The proposed methodology in this paper is using Loss Sensitivity analysis which been applied at the feeder in test systems to find the potential location to place DG in terms minimizing the total power losses in the distribution network.

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ABSTRAK

Dalam masa beberapa tahun ini, penggunaan Penjana Pembahagi atau dikenali sebagai 'Distributed Generation' (DG) ke dalam penyebaran jaringan telah meningkat. Ini adalah kerana kemajuan teknologi DG dan juga keadaan semasa dalam industri sistem kuasa. DG semakin dikenali kerana ia dianggap sebagai penyelesaian kepada masalah-masalah utama dalam industri sistem kuasa seperti mengurangkan kehilangan tenaga yang tinggi, mengurangkan kehilangan tenaga di jaringan, membaiki nilai voltan pada bus. Tesis ini bertujuan untuk mencari tempat sesuai untuk meletakkan DG didalam penyebaran jaringan untuk mengurangkan keseluruhan kehilangan tenaga dalam sistem, untuk mencadangkan pembaikan jaringan berdasarkan kewujudan DG. Cara untuk mencari lokasi yang sesuai untuk meletakan DG bermula dengan memulakan simulasi tentang penyebaran aliran beban bertujuan untuk mengetahui keadaan pada setiap bus dalam sistem. Simulasi dilakukan dengan menggunakan software DigSILENT PowerFactory untuk mencari lokasi sesuai untuk diletakkan DG. Cara yang dicadangkan untuk mencari lokasi sesuai untuk diletakkan DG adalah analisis Loss Sensitivity yang digunakan dibus yang boleh diharapkan untuk mencari tempat yang sesuai untuk diletakkan DG di dalam sistem untuk mengurangkan keseluruhan kehilangan tenaga pada sistem kuasa

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CHAPTER 1

INTRODUCTION

Energy can be defined as the capacity of doing work. There is many form of energy. One of them is electrical energy. Electrical energy is the energy in a useable form, which can be transformed to other energy forms. The electrical energy can be produced at one location and transmitted to another instantaneously. It been delivered by a system of wires and control. This whole system is called electrical power system. Electrical power system is a key infrastructure nowadays as it was the major source of the energy in the world. The good electrical power system will promote the highest technologies. Power system can be explained by dividing it into three major parts: generation, transmission and distribution. The power is generate at the generation plant and been transport through high voltage transmission line and been step down the voltage and distribute in distribution network.

1.1 New Interest in Distributed Generation

Conventionally, the power plant used to supply electricity in the close neighborhood. But as the demand rises, the electricity grid was invented to transport the electricity over the longer distances. The invention of electricity grid has leads to construction of massive electricity system such as huge transmission and distribution grids and larger generation plant as the electricity that been transport over longer distance has increased the power output of generation units [1] and indirectly has increased convenience and lower per unit costs. But this has causing increasing of transportation costs. Distributed Generator (DG) is an alternative way to reduce cost of transportation as it was installing near to the load.

Moreover with the rapid load growth demanding more flexible power system that suits their needs. The utility companies used to predict the load growth in certain place until the predetermine amount was reach. When the amount was exceed the predict amount, they usually expanding the new substation capacity or construct the new substation. This had driving to the development technologies DG that fits to the criteria of flexible system. For the utility companies, they see DG as the tool that can help them to survive in liberalized market.

At present, the environmental issues has been the major reasons DG been so popular. Customers want the energy that cleaner and has less impact to the environment. They tend to choose DG as alternative power generating because the DG not only use the fuel fossil but also can be generates electricity with renewable sources. Also it is accepted by many countries that reduction in gaseous emissions (mainly CO2) offered by DG is a major legal driver for DG implementation [2]. It also allows the optimizing

energy consumption of firms which has lager demand for both electricity and heat. For example, compared to fossil fuel generation, the CHP generation has result in a primary energy conversion, varying from 10% to 30%, depends on the size of the cogeneration units [1]. It has promotes less pollution by using the waste of flue gas to generate electricity. Also the energy such as sun and wind are free and absolutely clean.

Nowadays, the need for more quality of electric supply has become priority for consumer. They are aware of the value of reliable electric supply. There are several reliability problems that disturbing distribution networks. Apart from the large voltage drops to near zero, consumer can also suffered from smaller voltage deviations [1]. For example in radial networks, bus voltages happens to decrease as the distances from the distribution transformer increases and may become lower than the minimum voltage permitted by the utility [3]. By adding DG, the branches current were reduces which causing the reduction of losses and increasing of voltage through feeder.

In electric power systems, normally the energy losses occur in distribution networks. This is because the electricity supply has been transmitting in over longer distances. The longer the distances the more losses in electricity supply. In order to transmit the electricity over longer distances; the grid has been invented in a bulk and high voltage to reduce the loss that absorbs through the transmission. This has causing the transportation cost to increase. DG provides the most economic solution to reduce the transportation cost. Moreover, DG provides the most economical solutions to load variation. Under voltages or overloads that are created by load growth may only happens at the circuit for a small number of hours [4].

1.2 Placement Impact of Distributed Generation in Distribution Network

The electrical power system faces many problems when adding the DG in the existing networks, since the DG imposes many impacts on the distribution networks.

However, in order to get all the benefits, the DG must be put in strategically place. Finding the DG strategically allocation can result in a decrease in system losses which lead to decrease costs. DG affects the flow of power and voltage conditions at consumers and utility equipment [5]. The distribution system has been designed in passive network that is to operate in unidirectional power flow, from source to the loads. In the presence of DG, the distribution network becomes active networks with multidirectional power flow. The power flow can be reversed with the DG sending power in either direction from where it from. This has causing the disturbances of radiality. The strategically place of DG has been taken as priority due to this problem.

Although there are many advantages using the distributed generation, there are many issues that need consideration especially in technical issues such as the best allocation to install the distributed generation in order to get benefits from it. As the voltages to be within a specified limit, finding proper place to install DG is necessary as DG has greater effect on the voltage profiles along a feeder by changing the direction and magnitude of real and reactive power flows. DG can change the voltage where it is applied without having to change the voltage across the entire power system [6]. DG injected power has causing the voltage to be out of limits further downstream [7].

1.3 Thesis Organization

This paper proposes the analytical approaches to determine the optimal location for placing DG in network system. The process were observing at events, collecting data from the calculation and simulation, and analyzing information by comparing the result between calculation and simulation and reporting the result.

For this engineering project, the method that been proposed to find the strategically placement distributed generator (DG) in distribution networks is sensitivity analysis based on the voltage sensitivity and loss sensitivity. And also random technique that appropriate for the project also has been used as one of the method. For simulating the result that were obtain from the data, the DigSILENT Power Factory software were use as an analysis tool that combine reliable and flexible system modeling capabilities. The DigSILENT Power Factory software is an integrated power system analysis tool that combines both reliable factor and flexible system modeling capabilities to simulate the design.

This analysis study will focus on the presence DG which is the system losses, and power quality of the system. However, reliability, protection and economic impact are out of analysis study. The test system for this project is standard IEEE RS of 34 bus system been use to getting data from real utilities for the base case. For safety reasons, there is no testing and live measurement since the project was dealing with real high voltage system. The validation process is done by comparing with two different software or base comparison to tests recorded by the consultant.

1.4 Objectives of Project

The objectives of project are:

i. To determine the optimal location for placing distributed generation in network system to minimize power losses.
ii. To study the characteristics with and without DG.
iii. To propose the network improvement based on the presence of DG

1.5 Background

Electrical energy is the main source of energy nowadays. The electrical power system delivers the electrical energy to consumers which they use for variety of purposes. In return they pay for the energy that they consume. The electrical power system consist of three major parts; generation, transmission and distribution.

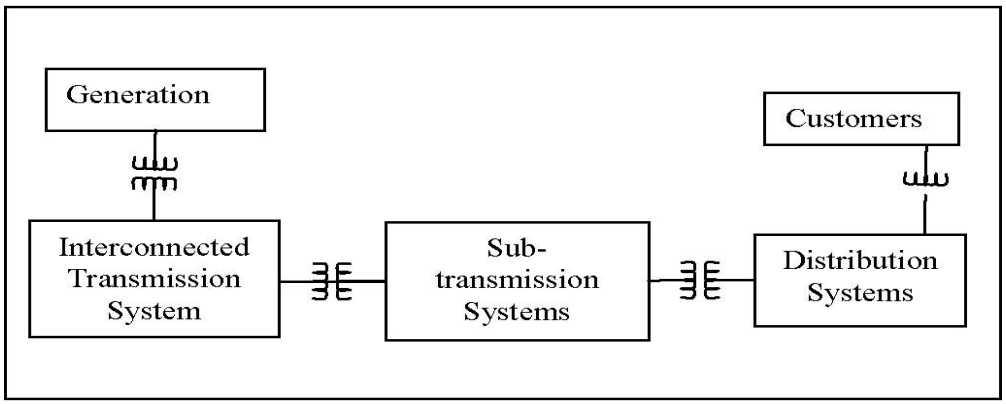

Figure 1.1 Typical Power System Components [8]

1.5.1 Generating Unit

The generation plant is used to convert the energy resources such as gas, coal and thermal into electrical energy in order to supply electricity requirements at all times. The electricity is produced in bulk at centralized station. The electricity is produced in remote place to avoid the pollution and construction of the huge structure require very large area as the generator very large and at times they are a group of two or more generators. The generation plant should be function in a reliable manner, involved maintaining the voltage and frequency stability of the network. It also should be avoid from disturbances which can jeopardize the correct functioning of the electrical power system.

1.5.2 Transmission Network

The electricity that been produced at remote area been transport via transmission line. The transmission system consists of three-phase transmission lines and connected to substation or switching stations. The transmission line usually installed in high voltage to decrease current amount thus reduces the cost of cable. There are 2 type of high-voltage transmission; high-voltage alternating current (HVAC) and high-voltage direct current (HVDC). The transmission line has three types; overhead, underground and submarine. A transmission network operates by a dispatching center or several regional dispatching centers. In general the transmission network is meshed. The power flow in each element of the networks can be calculated based on the inputs and the outputs of the electric power system.

1.5.3 Distribution System

The distribution system receives the voltages from high-voltage transmission lines and step down the voltage level to distribute to consumers according their needs. Distribution system operates either in radial or subnetworks to avoid overloading by the power flow coming from the electric transmission system mainly when some of the link failure to operate. Apart from the 3 major part of the electrical power systems, the distribution system plays the important role in the quality of serviced received by consumers. Good quality electric service requires acceptable range voltage level that suitable for their needs. The distribution system consist of passive electrical circuits which causing the active and reactive power fluxes flow from the high to low voltages. These fluxes are determined by loads. The voltage drops in the distribution networks are due to the active power circulation (R>>X) and the compensation of reactive power is mainly achieved at the consumer level because it forced by pricing [9].

1.5.4 Distributed Generation

Distributed generation or also known as embedded generation, on-site generation, dispersed generation, decentralized generation or distributed energy is a small plant generates electricity closed to the end user of power (connected to distribution network) and the capacity of DG is less than 100MW. It developed using the basis of cogeneration units, renewable energy system or traditional power generation. Some DG been installed at customer's premise and connected to the customer's side to directly supplied electricity. Others were connected to the distribution network to

provide the electricity supply to multiple customers. The use of DG has helps providing power impacts on the design and operation of bulk supply system including ancillary services.

Since early 19th the demand for electricity has increased. Due to the increasing load and generators can't be overloaded and the emerging of new technologies. DG not only economical but it also easy to install as it was small, easier to find sites and take short installation times. It also energy efficiency as it reduces loss. The natural gas which often used in distributed generation seems to be available in most consumer areas and offer stable price. This new technologies also flexible, reliable and helps promote power quality of electric services. By adding DG has created problems to distribution systems such as reverse power flow, system voltage (steady-state and transient) and the system stability.

1.5.5 Distributed Generation Technologies

Type	Size Range (kW)	Electrical Efficiency (%)	Applications
Reciprocating Engines	5-7000	25-45	Backup power, base load, grid support and peak shaving.
Fuel Cells	1-10000	40-65	Co-generation, grid support

Photovoltaic Arrays	<1-100	5-15	Base load, peak shaving
Stirling Engines	1-25	12-20	Vehicles, Refrigeration, Aircraft, Space
Wind systems	Several kW-5000	20-40	Remote power, grid support
Micro Turbines	30-500	20-30	Stand-by power, power quality, reliability, peak shaving, and cogeneration
Biomass energy	5-10000	40-50	Co-generation, grid support

Table 1.1: Options for small scale distributed generation [8]

These are the latest form of distributed generation. They are other technologies beside the listed ones. These technologies are the result of intensive research and development.

1.5.6 Power losses

Transmission lines transmit electricity to generator unit to the customer. The long distance of transmission lines has causing the losses of the system due to many factors such as thermal resistance, line impedance and many more.

The high voltage will reduce the fraction of energy loss to resistance. This is because for the given amount of power, a higher voltage reduces the current thus reducing the resistive losses.

CHAPTER 2

LITERATURE REVIEW

For this chapter, the literature review was mainly because the major policy issues that popular the DG. And also this chapter will discussing about the DG technologies that helps to popular back the DG and the placement techniques that been used to find optimal placement to allocate DG to minimize the power losses in the system.

2.1 Major Policy Issues of DG

Nowadays, with the emerging of new technologies has indirectly growth many industries that demand much of electricity. This growth has demands for more flexible

electric system, energy savings, changing regulatory and cleaner energy. This growth has leading to the development of distributed generation or DG. DG has cope the growing demand of electricity and render the certain activities sell-sufficient in terms of power productions thus savings energy [10]. Distributed generation (DG) defined as small scale electricity generation. DG is an alternative for expanding the new substations capacities and their associated new feeder or constructs the new substations [2] when the growths demand higher than existing demand of electricity. The utilities companies no longer have to predict about the load growth in certain places.

DG is expected to grow in the future. DG supplied the electricity to customer either by using the distribution networks or without distribution networks as DG normally was installing near to the loads. According to the M. Gandomkar, the main reasons for the increasing of DG is [7]; DG units are closer to customer so that the transmission and distribution costs are reduced, the latest technology has made available plants ranging in capacity from 10kW to 15kW, It is easier to find sites for small generators, usually DG plants require shorter installation times and the investment risk is not so high, CHP(Combined Heat and Power) groups do not require large and expensive heat network, natural gas, often used as fuel in DG stations is distributed almost everywhere and stable prices are to be expected, DG plants yield fairly good efficiencies especially in cogeneration and combine cycles, and lastly DG offers great values as it provides a flexible way to choose a wide range of combinations of cost and reliability.

By adding DG into the existing networks have impacts on the electric power system as the power system was not designed to existence of DG. According to Umar Nassem Khan there are few data that been need to consider before evaluating the impacts of DG in distribution networks. The data is size rating of the processor DG, type of DG power converter (static or rotating machine), type of DG prime energy source (such photovoltaic, wind or fuel cell), operating cycles, fault current contribution of DG, harmonics output content of DG, DG power factor under various operating conditions,